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(71) Applicant: QSOUND LABS INCORPORATED
Calgary, Alberta T1Y 5L3 (CA)

(72) Inventors:
- Cowleson, Brian
  Alberta T4B 2J8 (CA)
- Arthur, John
  Calgary, Alberta T2E 0L7 (CA)
- Cashion, Terry
  Kensington PO, Alberta T2N 1X2 (CA)

(74) Representative: Jackson, Richard Eric
Carpmaels & Ransford,
43 Bloomsbury Square
London WC1A 2RA (GB)

(54) **Qsound surround synthesis from stereo**

(57) The inventive mechanism produces multiple output signals 31, 32, 41, 42, 51, 52 from a two-channel stereo input signal 11, 12. The mechanism produces a first pair of output signals 31, 32 which retain the monaural information in the stereo input signal. The first pair of signals 31, 32 each comprise a combination of one of the input channels and filtered signal produced from a difference of both input channels 11, 12. The mechanism produces a second pair of output signals 41, 42 which lacks the monaural information. The second pair of output signals 41, 42 each comprise a combination of one of the input channels and an inverse filtered signal produced from a difference of both input channels. Q-filters 34, 43, 44 are used to provide the various filtered signals.

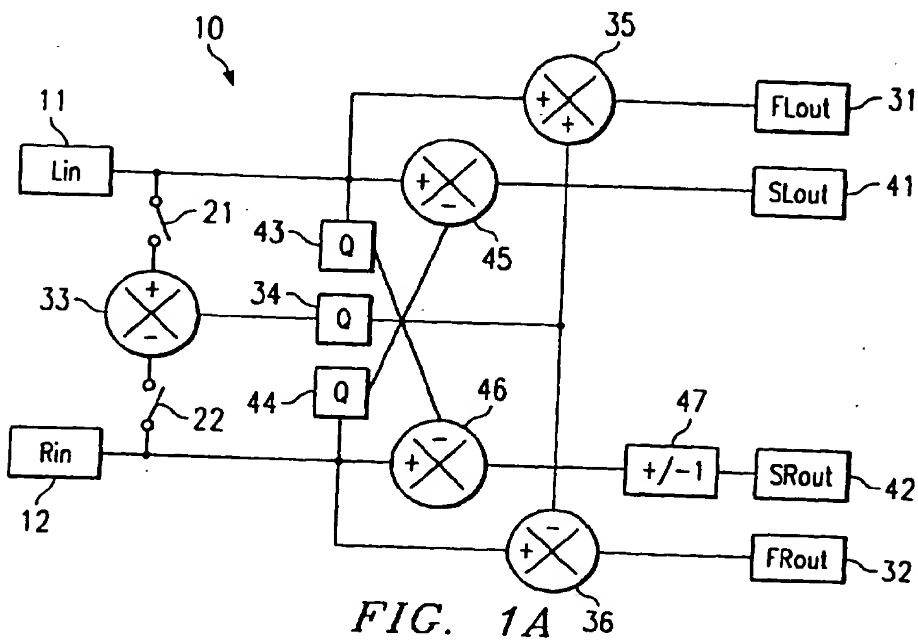

FIG. 1A

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Description

RELATED APPLICATIONS

[0001] The present application is a continuation in part of co-pending and commonly assigned U.S. Application Serial No. 08/858,586, entitled FULL SOUND ENHANCEMENT USING MULTI-INPUT SOUND SIGNALS filed May 19, 1997, which is incorporated herein by reference. The present application is related to co-pending and commonly assigned U.S. Application Serial No. 08/511,788, entitled STEREO ENHANCEMENT SYSTEM INCLUDING SOUND LOCALIZATION FILTERS, filed August 7, 1995, which is incorporated herein by reference, which is a continuation in part ofU.S. Patent No. 5,440,638.

TECHNICAL FIELD OF THE INVENTION

[0002] This application relates in general to audio signal processing, and in specific to synthesizing multiple output channels from two-channel, stereo input signals.

BACKGROUND OF THE INVENTION

[0003] A recent trend in the audio industry is the purchase and installation of home theater systems. Consumers have been purchasing multiple speaker sound systems which are integrated with a video system which uses VCR tapes and/or DVD disks. A similar trend is occurring in the automobile audio industry, wherein multiple speaker sound systems are being installed in automobiles and trucks.

[0004] In both of these cases, the input signal typically comprises a stereo or two-channel signal, which is being outputted on five or more speakers, each of which is capable of receiving a separate channel. Since there are more speakers than signals, the same signal is sent to multiple speakers. Thus, these audio systems are under utilized. Although there are a small number of recorded movies and/or sound CDs that are available, which have been recorded with the full five channel system, the vast bulk of audio/visual (A/V) entertainment information (including music CD's, VHS movies, television broadcasts) is recorded in the stereo or two-channel format.

[0005] Such systems typically handle stereo signals by sending the same signal to the front and rear speakers. For example, the front left and rear left speakers would receive the same left input channel. The amplitude of the signal can be controlled through a fader button which defines the portion of the signal going to the front speakers and the portion going the rear speakers. A sub-woofer channel can be created by summing the left and right channels and filtering out the high frequency information. Consequently, the multiple speaker systems are being under utilized when using stereo two-channel A/V information.

[0006] Therefore, there is a need in the art for a mechanism which will synthesize multiple channels of audio signals from a two-channel stereo input signal. This would allow an existing multiple channel audio system to output unique synthesized channels to each speaker.

SUMMARY OF THE INVENTION

[0007] These and other objects, features and technical advantages are achieved by a system and method which synthesizes multiple output channels or signals from a two-channel stereo signal.

[0008] The inventive mechanism uses several sub-systems to generate output signals from the stereo input signals. A first sub-system synthesizes the front left and front right signals, which include monaural information. A second sub-system synthesizes the surround (or rear) left and surround right signals, which have the monaural information canceled or greatly diminished. A third sub-system synthesizes the center signal and the sub-woofer low frequency signal. Thus, using a stereo input signal, the inventive mechanism can synthesize six different output signals. Each of the output signals can be directed to a different speaker.

[0009] A technical advantage of the present invention is to allow multiple channel audio systems to utilize their multiple channel capabilities and playback four or more channels synthesized from input materials recorded in two-channel stereo.

[0010] Another technical advantage of the present invention is that the center or monaural information is delivered by the front speakers or by a center speaker.

[0011] A further technical advantage of the present invention is that the center or monaural information is removed from the rear speakers.

[0012] The foregoing has outlined rather broadly the features and technical advantages of the present invention in order that the detailed description of the invention that follows may be better understood. Additional features and advantages of the invention will be described hereinafter which form the subject of the claims of the invention. It should be appreciated by those skilled in the art that the conception and the specific embodiment disclosed may be readily utilized as a basis for modifying or designing other structures for carrying out the same purposes of the present invention. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] For a more complete understanding of the present invention, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

FIGURES 1A and 1B depict the inventive system which outputs four-channels from a two-channel

stereo input;

FIGURE 2 depicts the inventive system which outputs six channels from a two-channel stereo input;

FIGURES 3A and 3B each depict an alternate sub-system of FIGURES 1 and 2 which create the left front and right front output channels;

FIGURE 4 depicts a sub-system of FIGURES 1 and 2 which creates the left rear and right rear output channels;

FIGURE 5 depicts a sub-system of FIGURE 2 which creates the center and sub-woofer output channels; and

FIGURES 6A and 6B depict the effects a switch in the sub-system of FIGURE 4.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0014] FIGURE 1A depicts the inventive arrangement 10 wherein a two-channel stereo input, from an A/V source, is converted into four-channel output signals, each of which can be sent to a different speaker. Left input 11 and right input 12 are sent through summers 35 and 36, respectively, to front left output 31 and front right output 32. FIGURE 3 shows this more clearly. Note that summer 36 includes an inverter, however, this inverter could reside within Q-filter 34. Similarly, summers 45 and 46 also are shown to have inverters, however, these inverters could reside with in Q-filters 44 and 43, respectively. Optionally, Q-filter 34 is switched into the circuit 10 by a user via switches 21, 22. A single switch could be placed between Q-filter 34 and summers 35,36 instead of switches 21, 22. The Q-filter 34 could be a QXpander filter, wherein QXpander is a registered trademark of QSound. The QXpander is described in U. S. Patent 5,440,638 to Lowe et al., which is hereby incorporated by reference. The Q-filter 34 could be a Q1 filter, which is described in U.S. Patents 5,105,462 and 5,208,860 both to Lowe et al., wherein each ofthese patents are hereby incorporated by reference. The output of summer 33 is L-R which is inputted into Q-filter 34, which adjusts the amplitude and phase of the signal on a frequency dependent basis. Note that summer 33 includes an invertor on the R input side, however, the invertor does not have to be a part of summer 33, but can be separate from the summer and be applied such that only that portion of the R input side going to summer 33 is inverted. This note applies to the other summers as well. The inversion multiplies the signal by -1, and therefore the polarity of the amplitude is changed. Any positive amplitude becomes negative and any negative amplitude becomes positive. This applies to the other summers as well.

[0015] The signal output from Q-filter 34 is then added to L input 11 by summer 35, which results in a (Q{L-R} + L) signal as front left output 31. The signal output of Q-filter 34 is also subtracted from R input 12 by summer 36, and results in (R-Q{L-R}) signal as front right output 32. Note that summer 33 could have the invertor on the L input side, which would require an inverter on summer 35, instead of summer 36, to invert the output from Q-filter 34. Switches 21,22 allow for a user to switch off the Q-filtering on the front channels and to have the Q-filter enhanced signals only on the rear or surround channels, thereby receiving the standard left and right stereo channels in the front speakers.

[0016] Each of the output signals 31 and 32 retains monaural or center information. For example, if the same sounds were in both the left and right channels, then an output of L-R would equal zero, because L=R. Therefore no monaural or center information is passed to the Q-filter 34, and the outputs 31 and 32 would be the inputs 11 and 12. This means that the monaural or center information is retained. In today's music, voice and drums tend to be in center information, with guitar and piano to the side information. Thus, the mid-panned or center panned sounds in the recorded mix appear in the front speakers.

[0017] Instead ofthe single Q-filter as shown in FIGURE 3A, an arrangement having two Q-filters can be used, as shown in FIGURE 3B. As stated earlier, Q-filter could be a QXpander filter, and thus both filters of FIGURE 3B could be QXpander filters. A difference of L input signal 11 and R input signal 12 is created by summer 38 and provided to Q-filter 34'. The output of Q-filter 34' is then inverted and added to R input signal 12 by summer 36'. The output from summer 36', R-Q{L-R}, is the R front output signal 32. Note that the R front output signal 32 of FIGURE 3B is the same as FIGURE 3A. Similarly, a difference of R input signal 12 and L input signal 11 is created by summer 39 and provided to Q-filter 34". The output of Q-filter 34" is then inverted and added to L input signal 11 by summer 35'. The output from summer 35', Q{L-R} + L, is the L front output signal 31. Note that the L front output signal 31 of FIGURE 3B is the same as FIGURE 3A. FIGURE 3B also retains the monaural information. Note that the input signal to each Q-filter, 34' and 34" is either L-R or R-L, if the scale multipliers 37 are set to 1. If the same sounds were in both the left and right channels, then L-R and R-L would equal zero, and thus, monaural information is not processed by the Q-filter, and the outputs of arrangement 30' is merely equal to the respective inputs. The arrangement of FIGURE 3B could include switches 21 and 22 as shown in FIGURE 3A. FIGURE 3B includes scale multipliers 37, each independently operable, for introducing an attenuation in the signal going into the negative input of summers 38 and 39. The scale multipliers control how much monaural or center information is passed to the Q-filters. In the extreme case where the attenuation is set to infinity, there is no signal sent to the

summers 38 and 39 from the opposite input signal. Hence, all of the monaural information is passed to the Q-filters. This results is a severe loss of monaural energy at the outputs 31 and 32. The arrangement of FIGURE 3B can be substituted for the arrangement of FIGURE 3A shown in FIGURES 1 and 2, if the scale multipliers 37 are set to 1. This arrangement will duplicate the effects of FIGURE 3A, however the scale multipliers 37 can be adjusted to provide control over the balance of the center information. The arrangement of FIGURE 3A can also be fitted with scalers. Note that a scale multiplier could be placed before each of the summers in FIGURES 1A, 1B, 2, 3A, 3B, 4, and 5, and would be used to control the amount of signal energy reaching the summer.

[0018] L input 11 is also connected to Q-filter 43 as shown in FIGURE 1. This is more clearly shown in FIGURE 4. Also, R input 12 is connected to Q-filter 44. Both of these filters may be Q1 filters. The output each Q-filter is subtracted from the opposite input via summers 45 and 46. For example, the output of Q1 filter 44 is subtracted from L input 11 and used as the left rear or surround output 41. Right rear or surround output 42 is similarly formed from the output of Q-filter 43 subtracted from the R input. In this instance the outputs are L-Q{R} for L rear output 41 and R-Q{L} for R rear output 42, and thus the center information is canceled out. If the same sounds were in both the left and right channels, then an output 41 would be nearly zero. This is similar for the right rear output 42. In today's music, voice and drums tend to be in center information, with guitar and piano to the side information. With the center information canceled out, the side-panned sounds in the recorded mix appear dominant in the rear speakers. Therefore, the arrangement of FIGURE 1A receives a stereo input signal, 11 and 12, and synthesizes four different output signals, 31, 32, 41, and 42.

[0019] Switch 47 is a user selectable phase inverter following the output of summer 46, which allows the user to turn off the expansion effect of the circuit of FIGURE 4. In FIGURE 6A the switch is turned on (+1), enabling the expander effect. Note that the portions 63, 64 of sound energy of the signal is spread beyond the locations of the speakers 61 and 62. In FIGURE 6B, the switch is turned off (-1), and the energy 65 does not spread beyond the locations of the speakers 61,62. Note that the monaural information is still suppressed, even though the switch is off. Switch 47 could alternatively be placed on the output of summer 45. Note that the Q-filter processed signals are normally inverted between the two output channels. When the R output signal is inverted, the necessary inversion between the two output channels is lost, and hence the virtual image effects are turned off. Switch 46 inverts or reverses the sign of the amplitude of the signal.

[0020] The filters of FIGURES 3A, 3B and 4, are all IIR or Infinite Impulse Response type. This type of filter has a feedback loop, which cause the output signal to last longer. The filter could alternatively be of the FIR type or Finite Impulse Response. The Q-filters can be implemented as IIR or FIR filters in digital domain. The Q-filters can also be implemented in the analog domain. The Q-filter in FIGURE 3A is preferably a two-stage filter. The Q-filters in FIGURES 3B and 4 are preferably a one-stage filter. However all of the filters could comprise one or more stages.

[0021] The arrangement 10' of FIGURE 1B depicts an alternative to the arrangement of FIGURE 1A. However, only two Q-filters are used, 43' and 44'. The outputs of these filters are combined with the input signals by summers 33', 35', 36', 45', and 46' to produce output signals 31', 32' 41, and 42. Note that the output signals 41 and 42 are identical to the output signals 41 and 42 of FIGURE 1A, namely L-Q{R} and R-Q{L}, respectively. However, the outputs 31' and 32' appear different than 31 and 32 of FIGURE 1A. The output 31' is Q{L} - Q{R} + L, which is different from Q{L-R} + L output 31. However, since the Q-filters are linear, then the Q-function is distributive, and thus Q{L-R} equals Q{L} - Q{R}. Therefore, output 31' is the same as output 31, so long as the Q-filter is operating in a linear fashion. This is also true for output 32' and output 32. The switch 47 appearing in FIGURE 1A could also be used in FIGURE 1B. A single switch placed between summer 33' and summers 35', 36' could be used instead of switches 21 and 22. The arrangement of FIGURE 1B could also replace that of FIGURE 1A in FIGURE 2.

[0022] The arrangements of FIGURES 1A and 1B are better suited to four-speaker sound systems. FIGURE 2 depicts the arrangement that is preferable for systems having a center speaker and a sub-woofer. Note that the system of FIGURE 2 could be modified for a five speaker system, i.e. having either just a center or a sub-woofer. The sub-systems of FIGURES 3A or 3B, and 4 are present in FIGURE 2. Moreover, FIGURE 2 includes the sub-system of FIGURE 5. In FIGURE 5, L input 11 and R input 12 are added together by summer 53, essentially creating a monaural output. The output of summer 53 is filtered by high-pass filter 54 with a cutoff frequency of about 100 Hz, and used as center output 51. The output is also filtered by low-pass filter 55 with a cutoff frequency of about 100 Hz, and used as sub-woofer output 52. Note that the recited cutoff frequencies are by way of example only. Therefore, the arrangement of FIGURE 2 receives a stereo input signal, 11 and 12, and synthesizes six different output signals, 31, 32, 41, 42, 51, and 52.

[0023] Although the present invention and its advantages have been described in detail, it should be understood that various changes, substitutions and alterations can be made herein without departing from the spirit and scope of the invention as defined by the appended claims.

Claims

1. A system for synthesizing multiple output channels from a stereo input signal, the system comprising:

    first means for synthesizing a first pair of output signals 31, 32 having monaural information from the stereo input signal 11,12; and
    second means for synthesizing a second pair of output signals 41, 42 having monaural information substantially removed from the stereo input signal 11, 12.

2. The system of claim 1, further comprising:
    third means for synthesizing a center monaural signal 51 from the stereo input signal 11, 12, wherein said third means comprises:

    a summer 53 which combines the stereo input signals 11, 12 to form a combined signal; and
    a high pass filter 54, which is applied to the combined signal and forms the center monaural signal 51.

3. The system of claim 1, further comprising:
    fourth means for synthesizing a sub-woofer signal 52 from the stereo input signal 11, 12, wherein said fourth means comprises:

    a summer 53 which combines the stereo input signals 11, 12 to form a combined signal; and
    a low pass filter 55, which is applied to the combined signal and forms the sub-woofer signal 52.

4. The system of claim 1, wherein the first means comprises:

    a first summer 33 for combining the one channel 11 of the stereo signal 11, 12 with an inverse of the other channel 12 of the stereo signal to form a difference signal;
    a first filter 34 for adjusting an amplitude and phase of the difference signal on a frequency dependent basis to form a filtered signal;
    a second summer 35 for combining the filtered signal with the one channel 11 to form one signal 31 of the first pair of output signals 31, 32;
    a third summer 36 for combining an inverse signal of the filtered signal with the other channel 12 to form the other signal 32 of the first pair of output signals 31, 32; and
    means 21, 22 for switchably controlling an operation of said first filter.

5. The system of claim 1, wherein the second means comprises:

    a first filter 43 for adjusting an amplitude and phase of the one channel 11 of the stereo signal 11, 12 to form a first filtered signal;
    a second filter 44 for adjusting an amplitude and phase of the other channel 12 of the stereo signal 11, 12 to form a second filtered signal;
    a first summer 45 for combining an inverse signal of the second filtered signal with the one channel 11 of the stereo signal 11, 12 to form one signal 41 of the second pair of output signals 41, 42; and
    a second summer 46 for combining an inverse of the first filtered signal with the other channel 12 of the stereo signal 11, 12 to form the other signal 42 of the second pair of output signals 41, 42.

6. A method for synthesizing multiple output channels from a stereo input signal, the method comprising the steps of:

    synthesizing a first pair of output signals 31, 32 having monaural information from the stereo input signal 11, 12; and
    synthesizing a second pair of output signals 41, 42 having monaural information substantially removed from the stereo input signal 11, 12.

7. The method of claim 6, further comprising the step of:
    synthesizing a center monaural signal 51 from the stereo input signal 11, 12, wherein said step of synthesizing a center monaural signal comprises the steps of:

    combining 53 the stereo input signals 11, 12 to form a combined signal; and
    high pass filtering 54 the combined signal to form the center monaural signal 51.

8. The method of claim 6, further comprising the step of:
    synthesizing a sub-woofer signal 52 from the stereo input signal 11, 12, wherein said step of synthesizing a sub-woofer signal comprises the steps of:

    combining 53 the stereo input signals 11, 12 to form a combined signal; and
    low pass filtering 55 the combined signal to form the sub-woofer signal 52.

9. The method of claim 12, wherein the step of synthesizing a first pair of output signals comprises the steps of:

    combining 33 the one channel 11 of the stereo signal 11, 12 with an inverse of the other chan-

nel 12 of the stereo signal 11, 12 to form a difference signal;
adjusting 34 an amplitude and phase of the difference signal on a frequency dependent basis to form a filtered signal;
combining 35 the filtered signal with the one channel 11 to form one signal 31 of the first pair of output signals;
combining 36 an inverse signal of the filtered signal with the other channel 12 to form the other signal 32 of the first pair of output signals 31, 32; and
switchably 21, 22 controlling a performance of the step of adjusting.

10. The method of claim 6, wherein the step of synthesizing a second pair of output signals comprises the steps of:

adjusting 34 an amplitude and phase of the one channel 11 of the stereo signal 11, 12 to form a first filtered signal;
adjusting 44 an amplitude and phase of the other channel 12 of the stereo signal 11, 12 to form a second filtered signal;
combining 45 an inverse signal of the second filtered signal with the one channel 11 of the stereo signal 11, 12 to form one signal 41 of the second pair of output signals 41, 42; and
combining 46 an inverse of the first filtered signal with the other channel 12 of the stereo signal 11, 12 to form the other signal 42 of the second pair of output signals 41, 42.

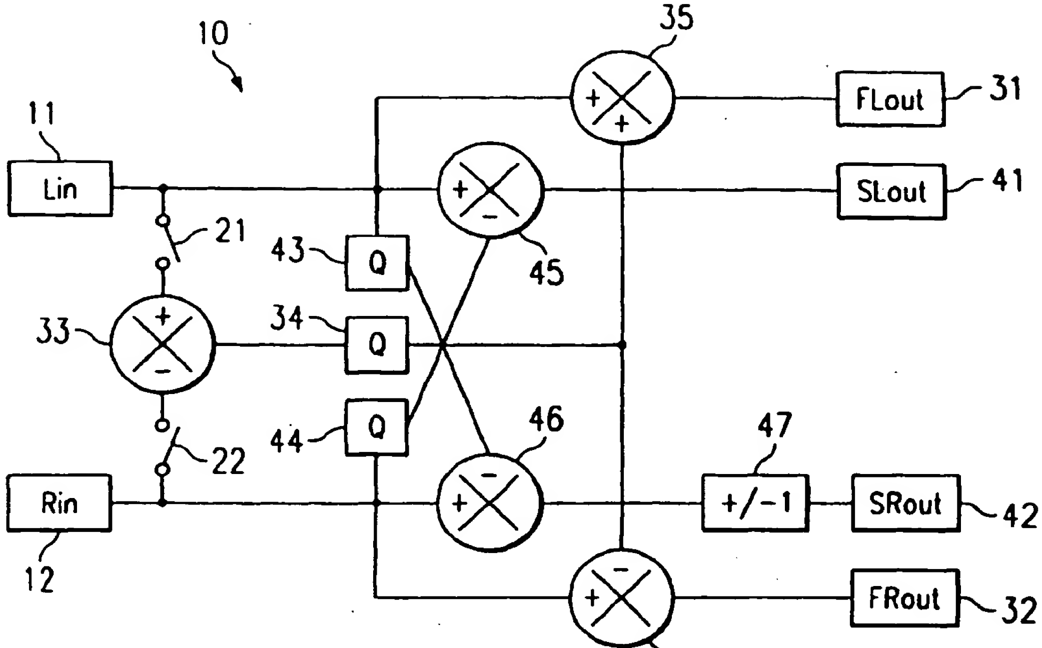
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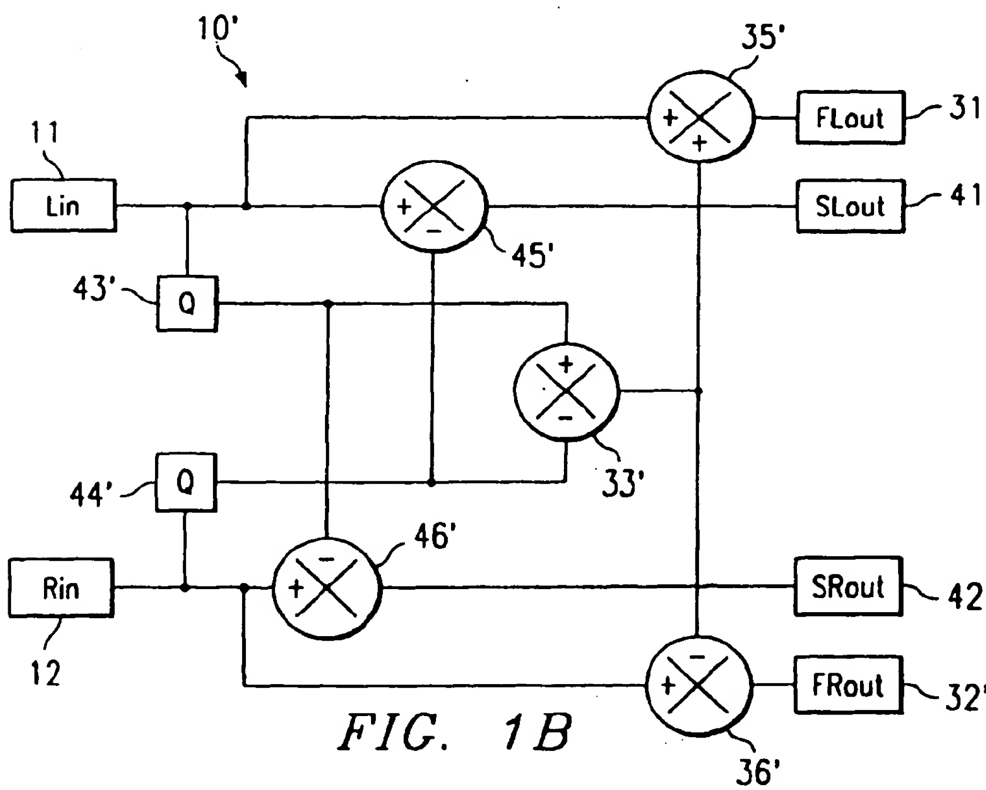
FIG. 1A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43'
44'
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FIG. 1B

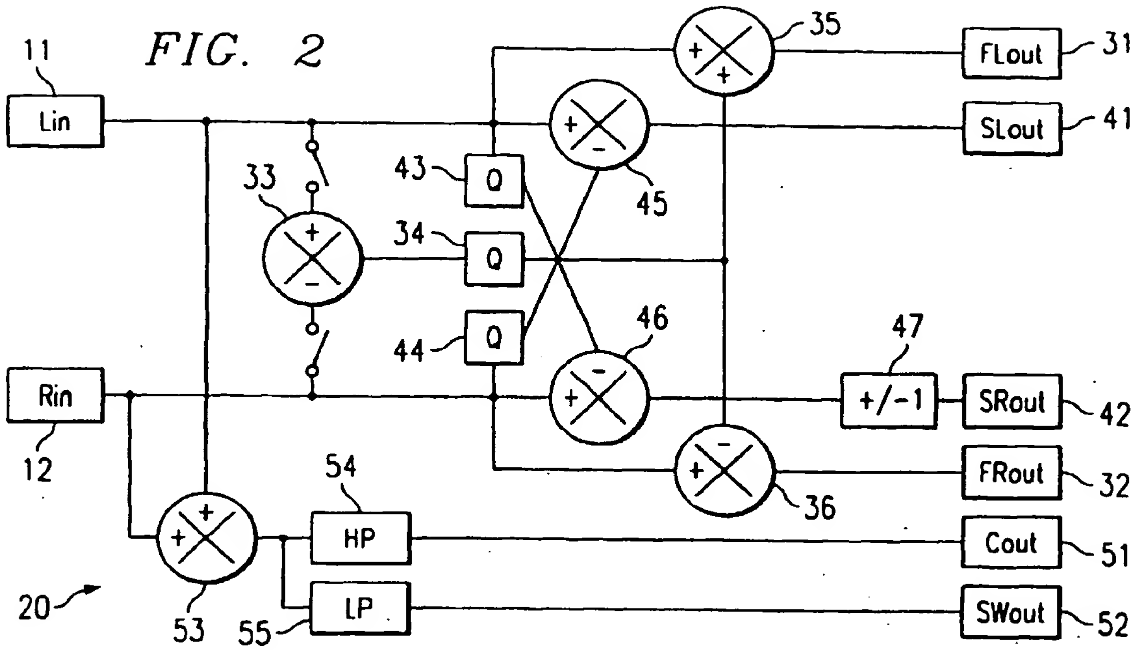

FIG. 2

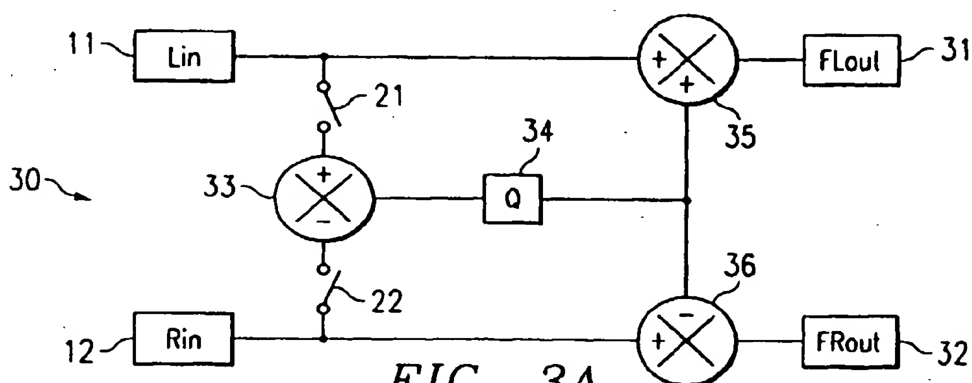

FIG. 3A

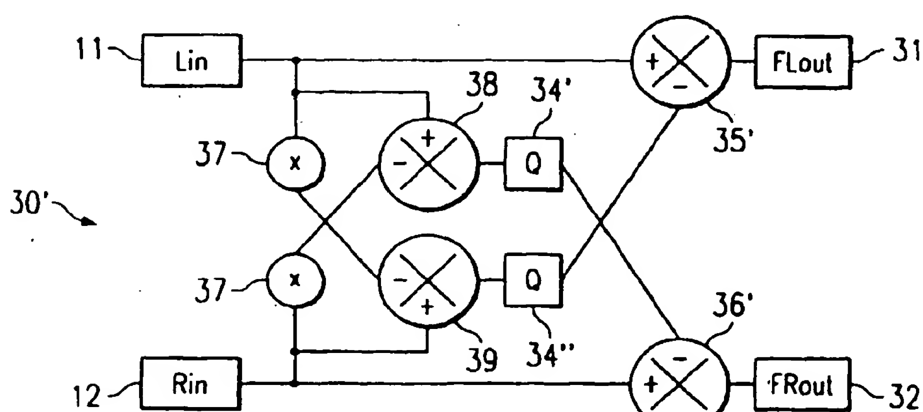

FIG. 3B

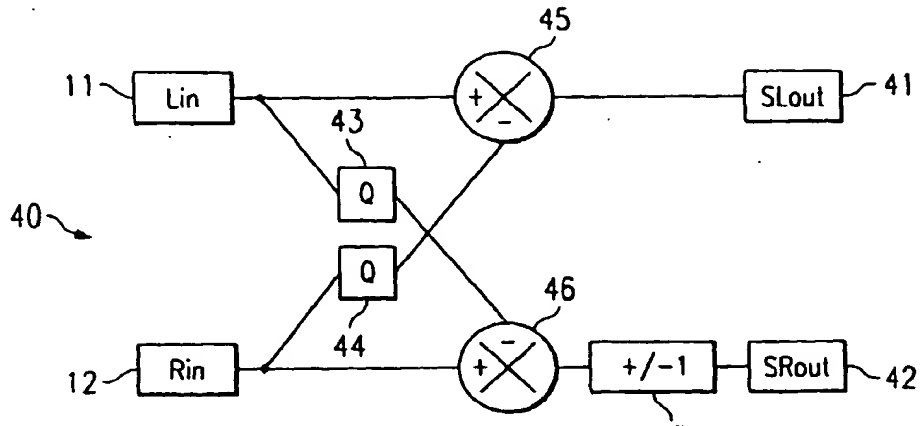

FIG. 4

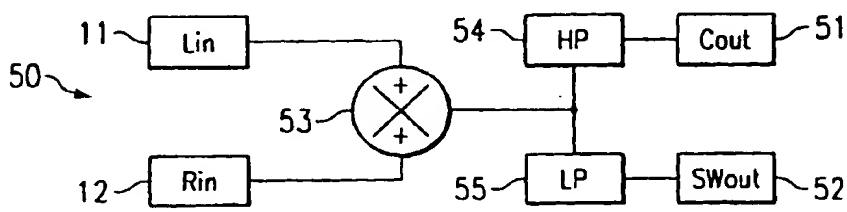

FIG. 5

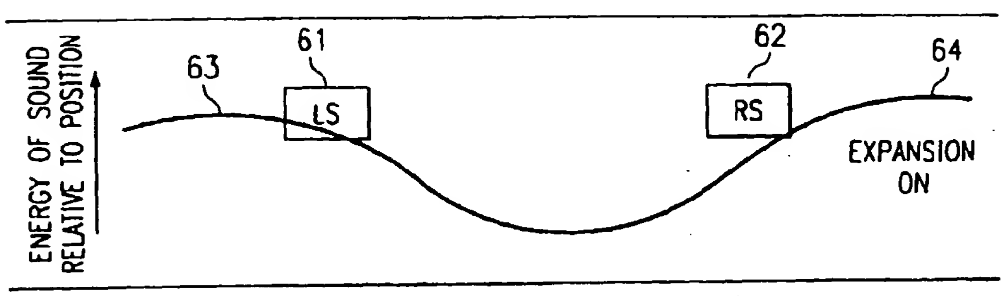

FIG. 6A

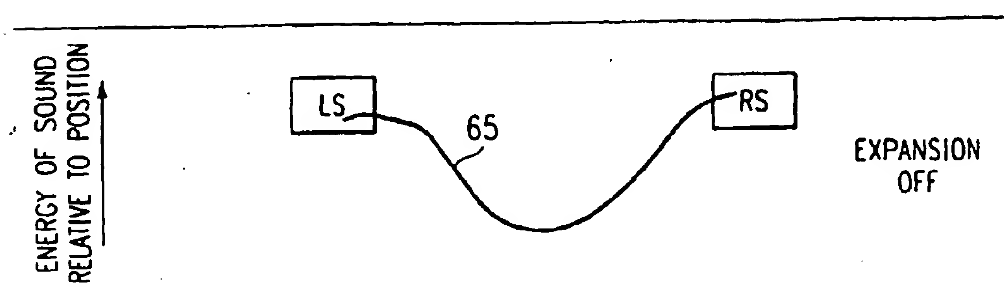

FIG. 6B